Rover Traverse Science

Onboard Autonomous Science Investigation System

OASIS Leads

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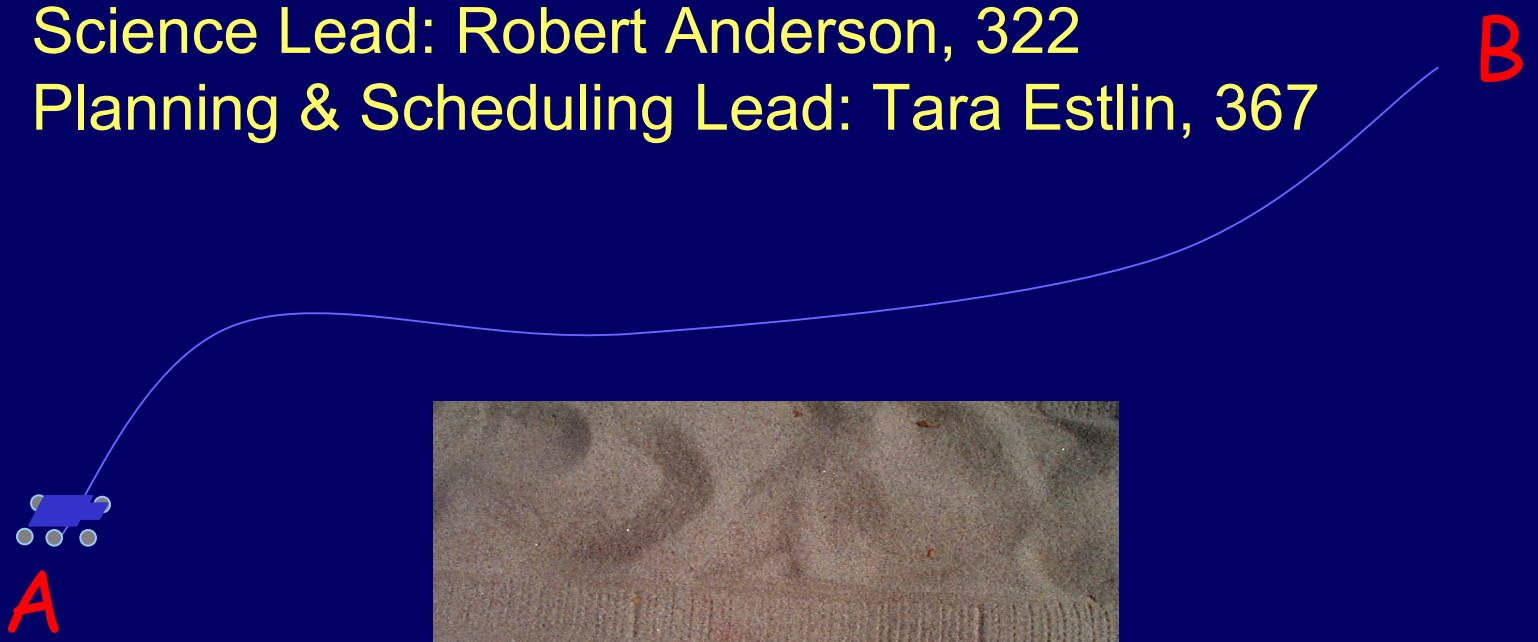
Science Lead: Robert Anderson, 322
Planning & Scheduling Lead: Tara Estlin, 367



July 23, 2002

CL#: 02-2848

Agenda

Overview of traverse science

Scientific motivation

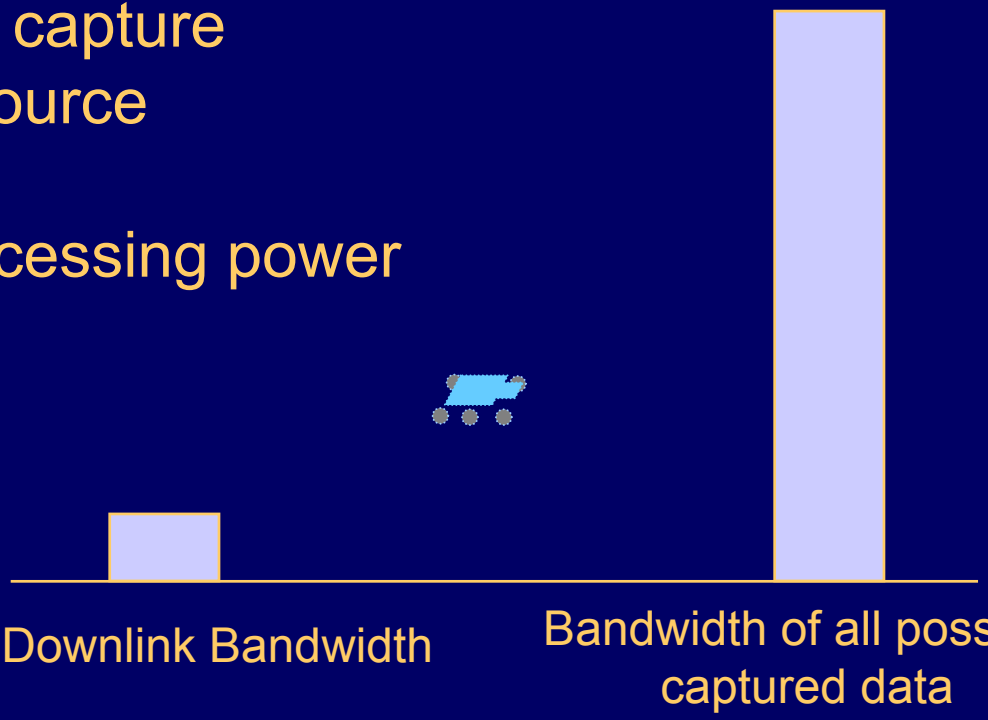
Technology under development

- Data analysis
- Data prioritization and summary
- Planning and scheduling
- Software validation

Conclusions

What is the Problem?

- Scientists want all the data!
- Rovers are getting larger and driving farther -- thereby creating MORE DATA
- But there are *limited* resources, such as
  - not enough bandwidth to downlink all data that instruments can capture
  - limited DSN resource
  - power
  - storage and processing power

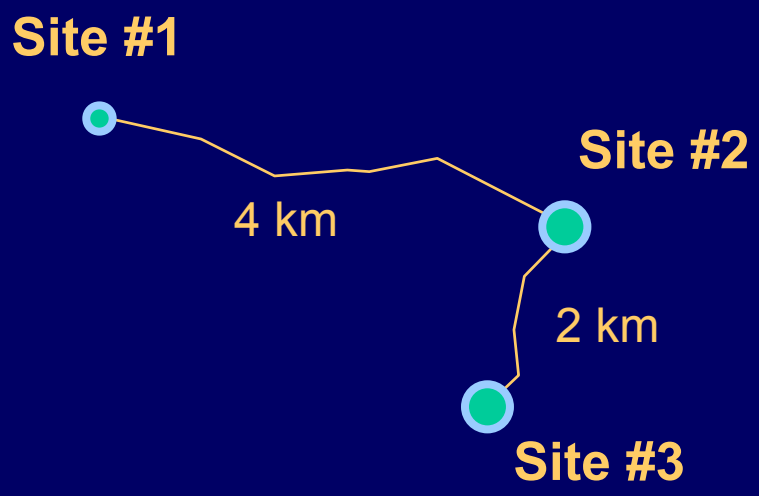


Solutions?

1) Increase the DSN capability
2) Compress all data
3) Restrict the quantity of data collected
   - Drive but do not collect data!
   - Collect at random times/locations
   - Collect at fixed time/distance intervals
   - Collect at pre-selected locations
4) Intelligently select data for downlink or compression by analyzing science data onboard (prioritization)
5) Summarize data using onboard science data analysis

Possible Mission – Overview

Numerous locations to visit which may require a several kilometer traverse between locations



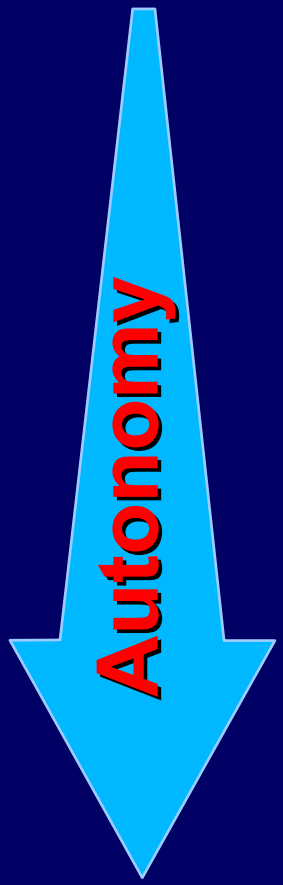
What is Traverse Science?

Collecting science information while traveling from point A to point B

Traverse Science Goals

- Identify pre-specified key targets
  - signs of water
- Identify novel, unexpected objects
- Catalog and summarize terrain covered

Traverse Science Options



1) Prioritize images (Navcam) collected during traverse for downlink

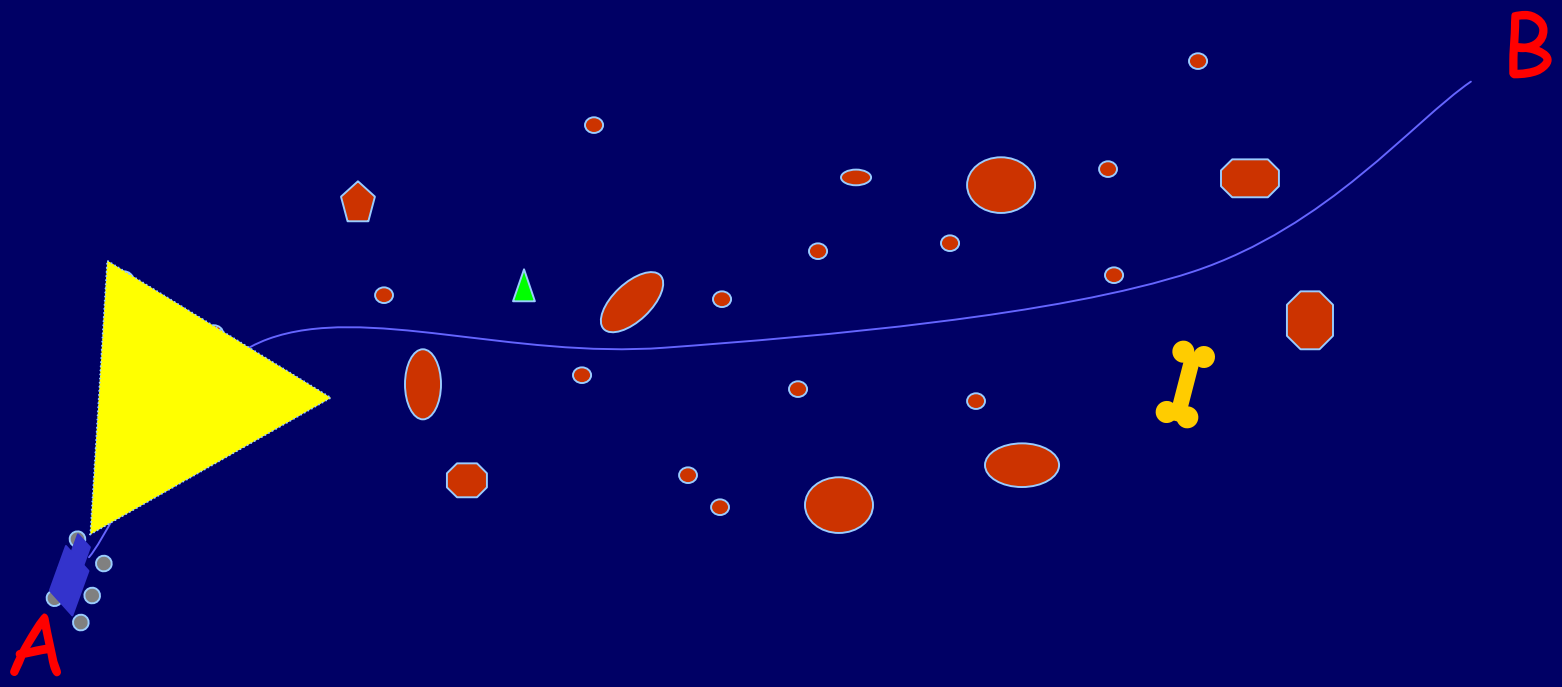
2) Collect inexpensive extra data of potentially interesting objects

3) Slightly adjust path to get better view of a very interesting object

4) Approach and take contact measurement of an extremely interesting object

Traverse Science Example

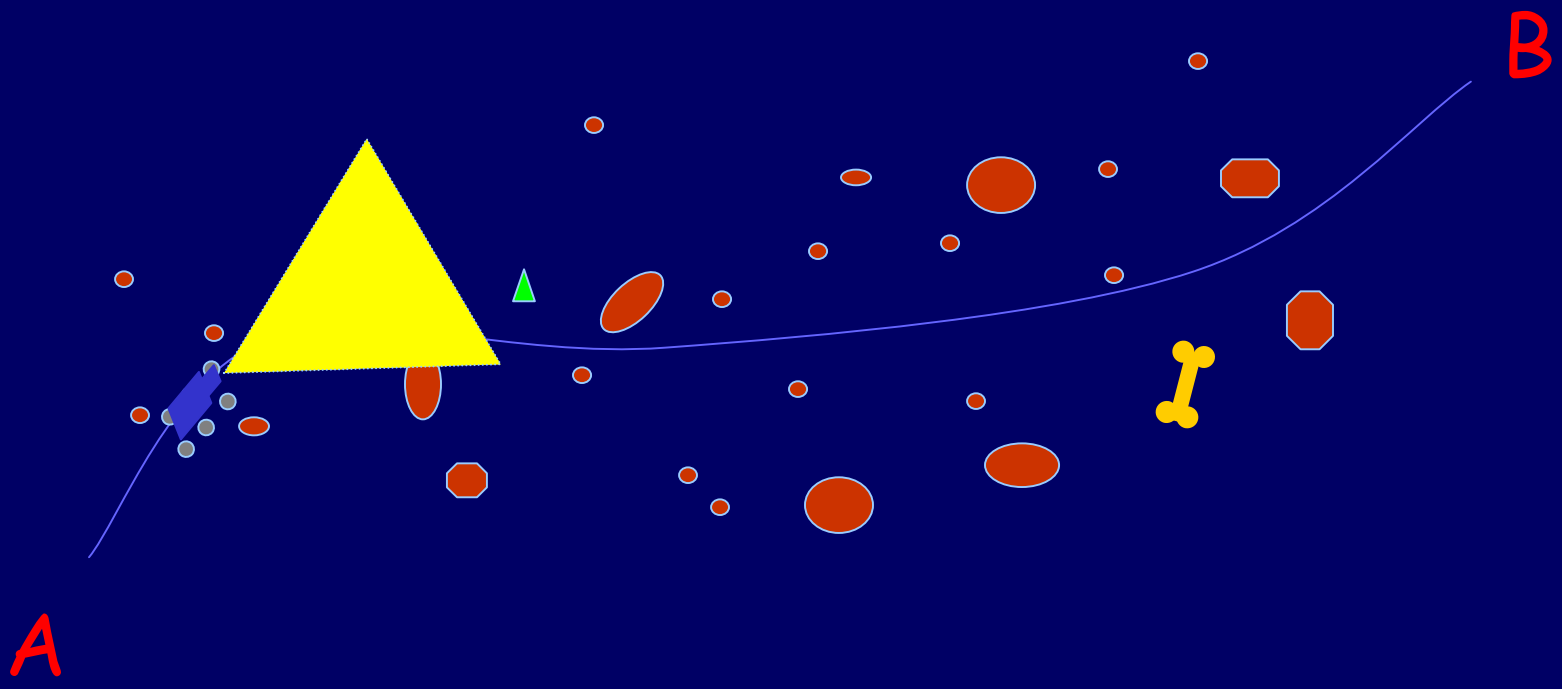
Onboard Autonomous Science Investigation System



Analyze Navcam images for science targets

Traverse Science Example

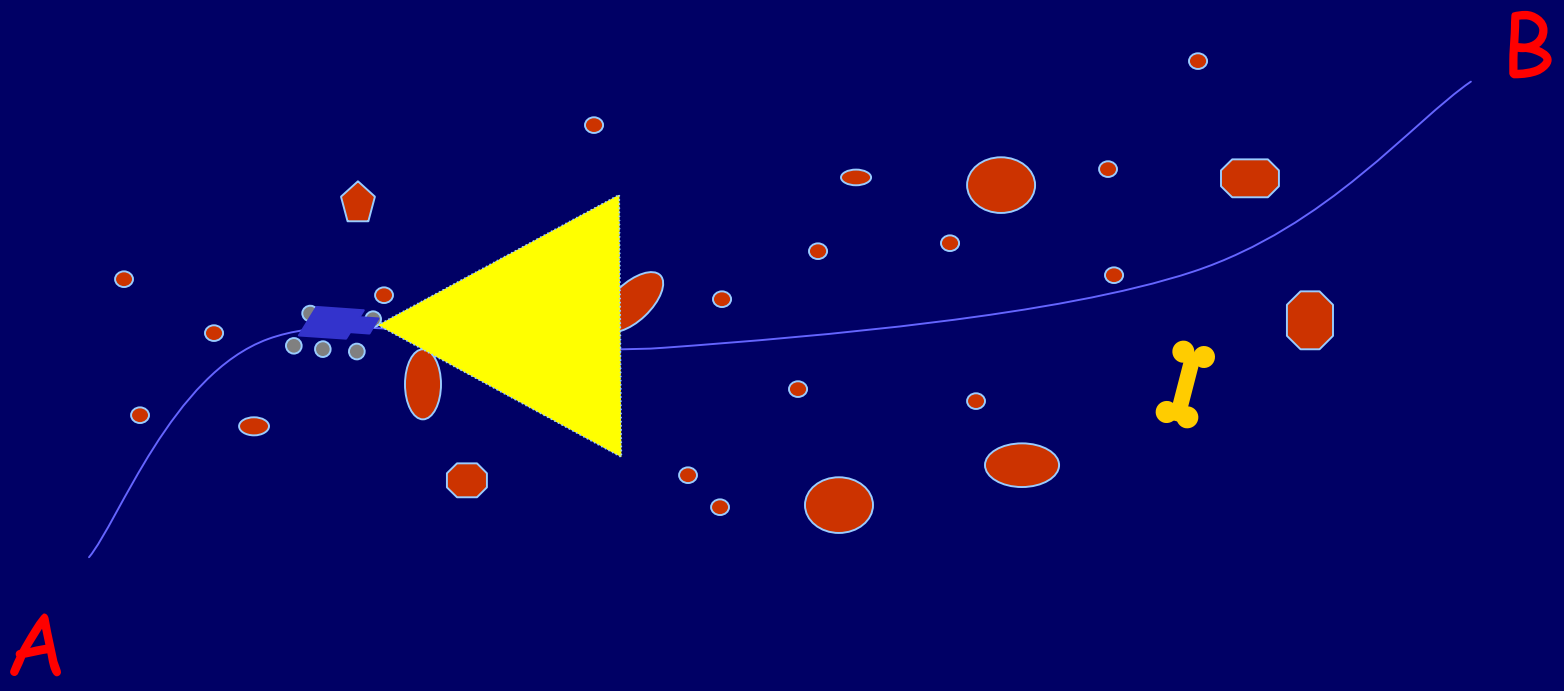
Onboard Autonomous Science Investigation System



Compile summary information on region

Traverse Science Example

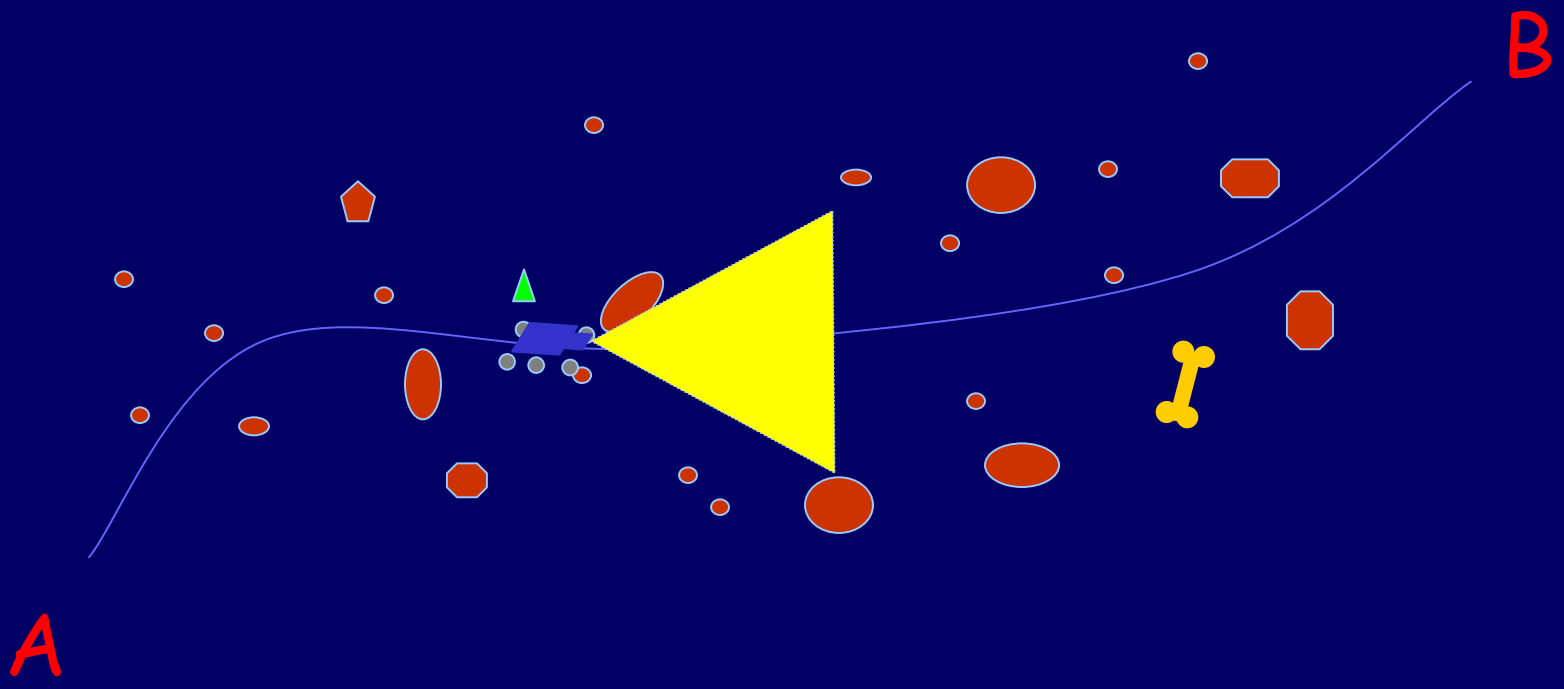
Onboard Autonomous Science Investigation System



Potentially interesting object detected
-> take a color image

Traverse Science Example

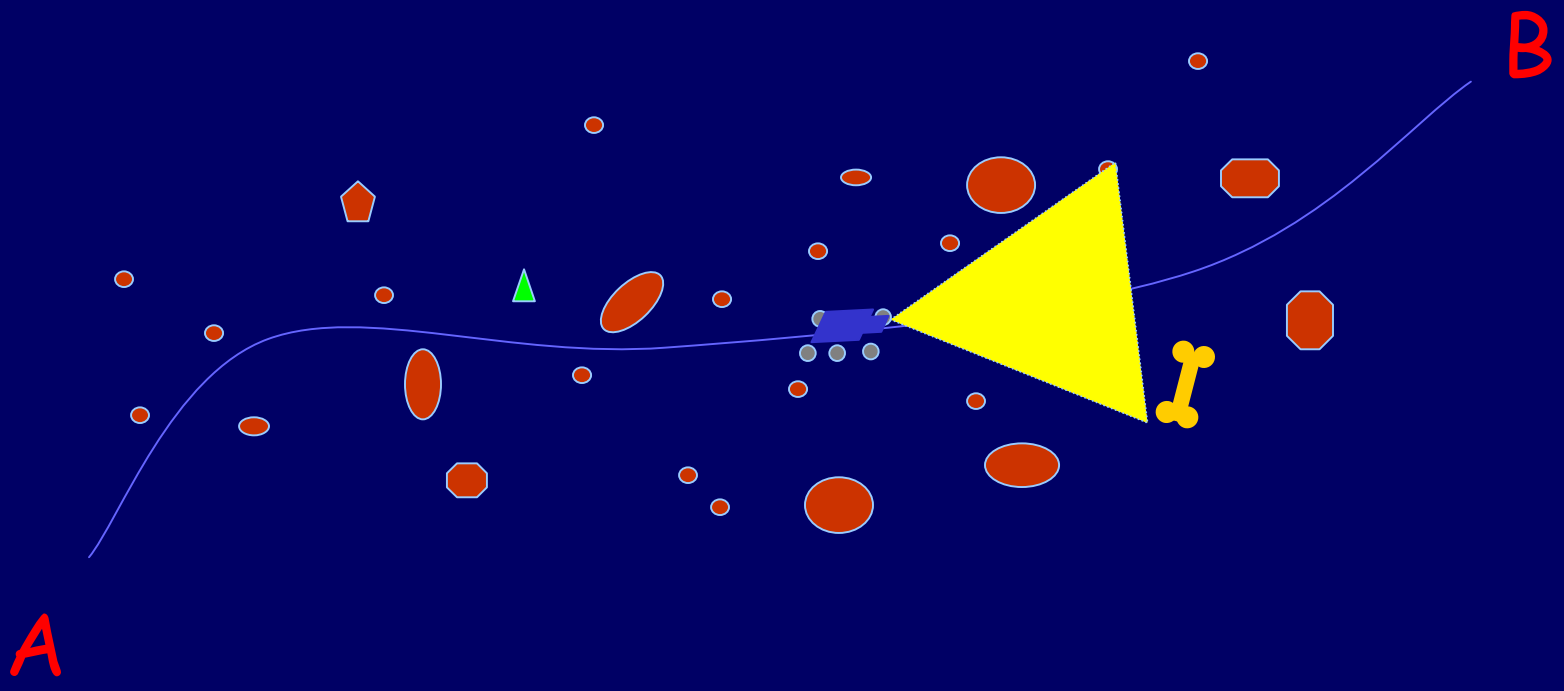
Onboard Autonomous Science Investigation System



Continue analyzing Navcam images

Traverse Science Example

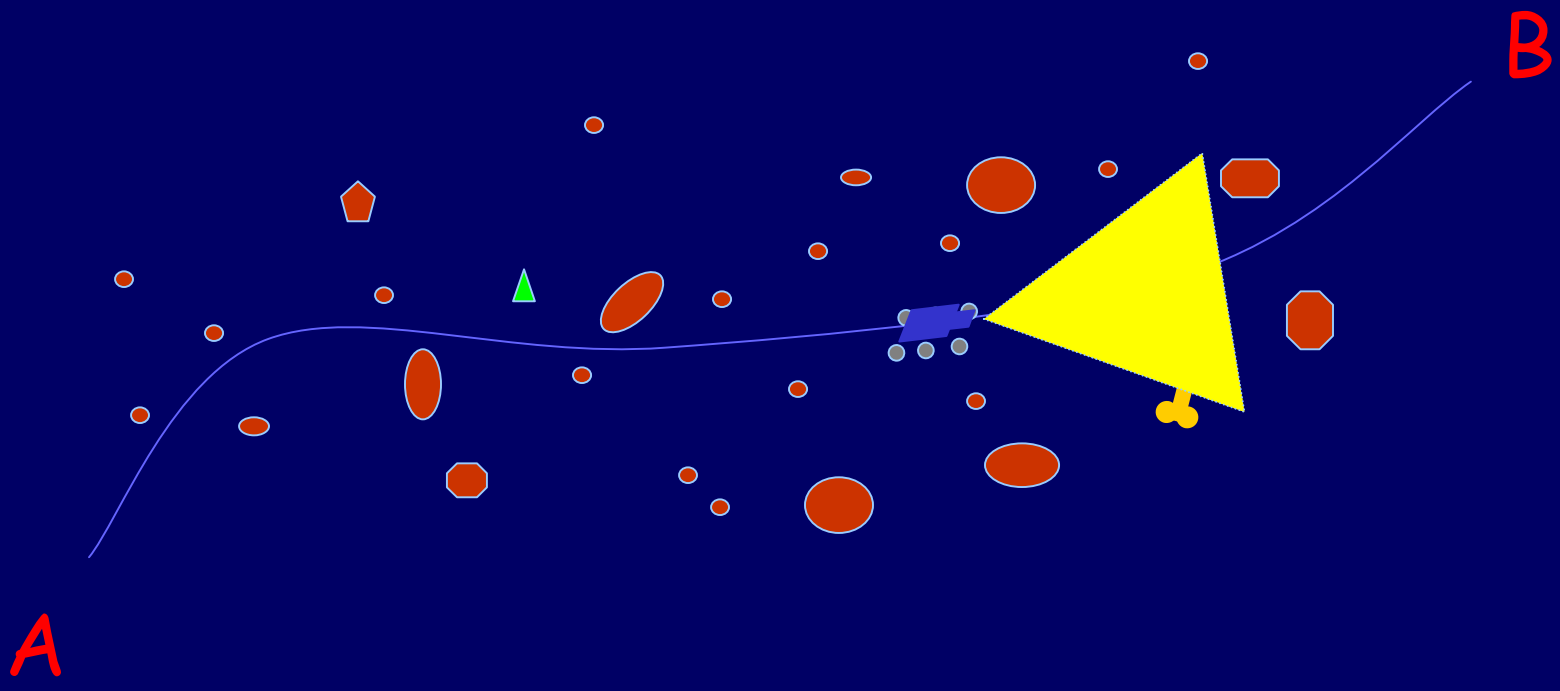
Onboard Autonomous Science Investigation System



Continue analyzing Navcam images

Traverse Science Example

Onboard Autonomous Science Investigation System

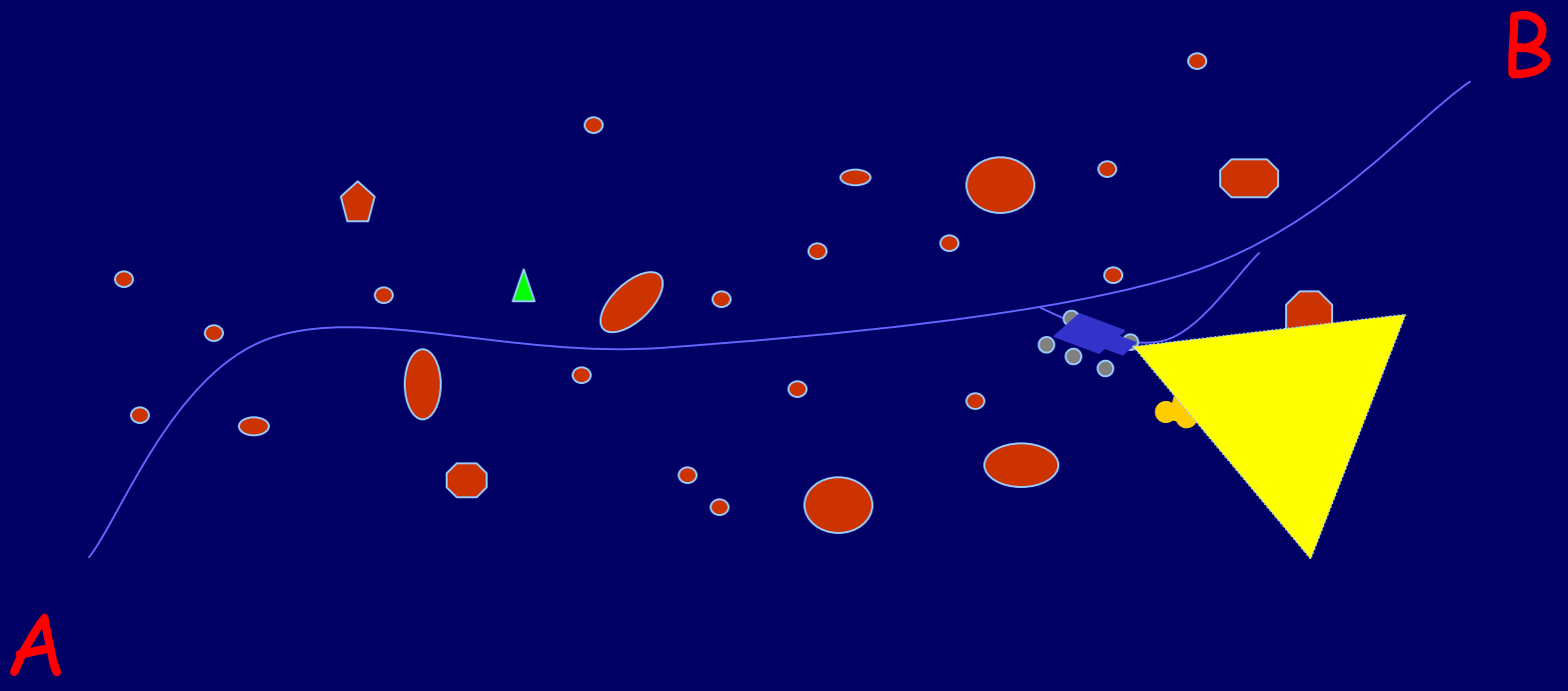


Potentially interesting object detected

-> take a color image or spectrometer measurement

Traverse Science Example

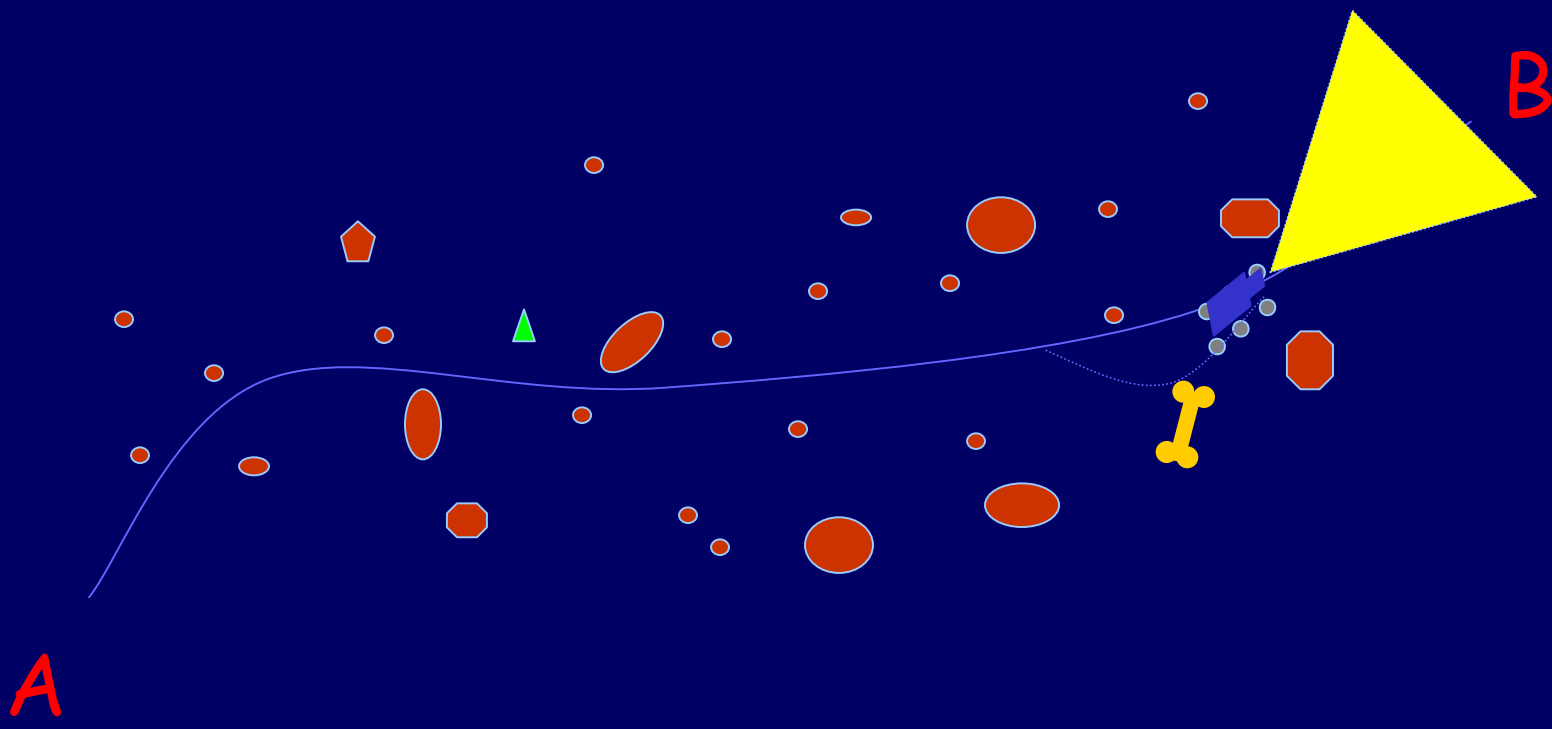
Onboard Autonomous Science Investigation System



Object appears to be very interesting
-> slightly adjust course to improve view of object

Traverse Science Example

Onboard Autonomous Science Investigation System



Proceed along path to destination

Agenda

Overview of traverse science scenarios

Scientific motivation

Technology under development

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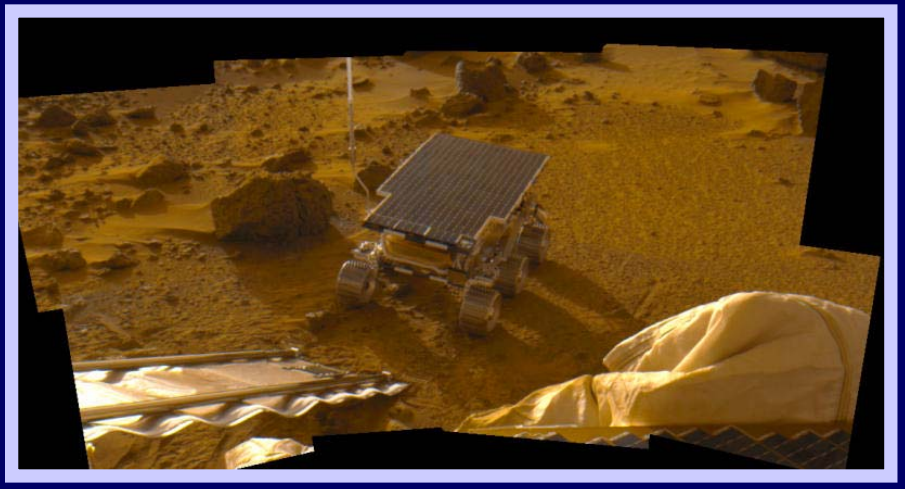
- Data prioritization and summary
- Planning and scheduling
- Software validation

Conclusions

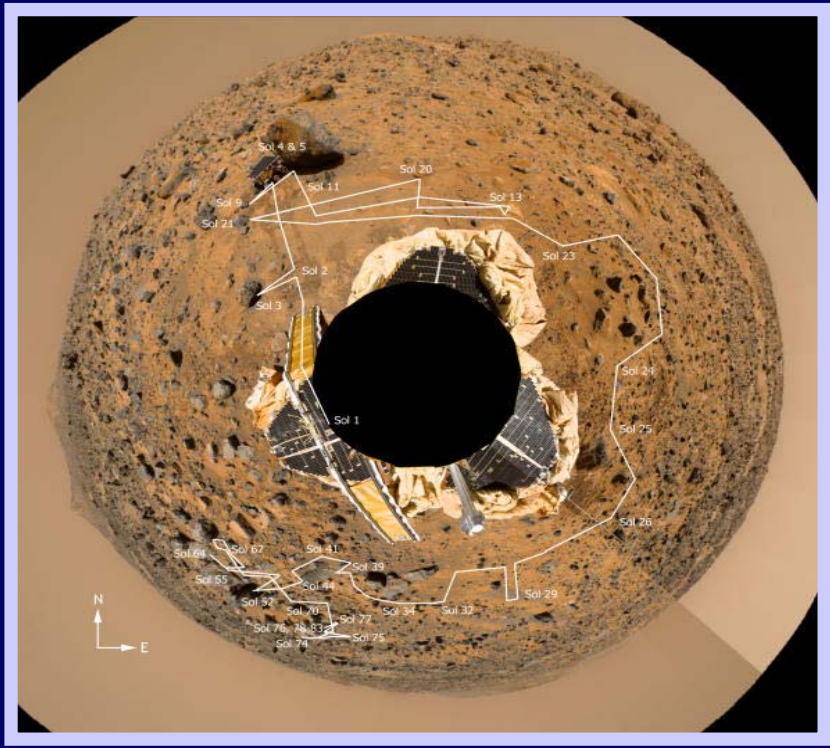


Why Traverse Science?

- Takes a long time to do “science”
- Helps to resolve the conflict between long driving requirements and science - geologists are afraid they are going to miss opportunities for science
- Not trying to replace geologists on the mission
- Increase total mission science return

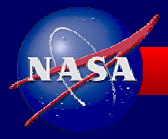
Lessons Learned - MPF

Onboard Autonomous Science Investigation System

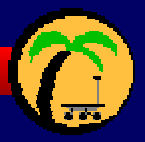


- How to:
  - Land in airbags
  - Drive a rover
  - Navigate a rover on another planet
  - Surface science
- Limited mobility due to line-of-sight communications
- Limited resources --> Limited science return
- The amount of time it takes to “do” science

Lessons Learned: 2001 FIDO Field Test



Onboard Autonomous Science Investigation System



- Can do in-depth science on a small region.
- Meet the minimum science requirements.
- Still have a lot of “dead time” for operations --> Scientist stay in one area too long to maximize science return
- Choose targets based on short traverses.
- Did not meet minimum mission criteria for rover mobility.
- Missed the “Rosetta” stone

Future Rovers

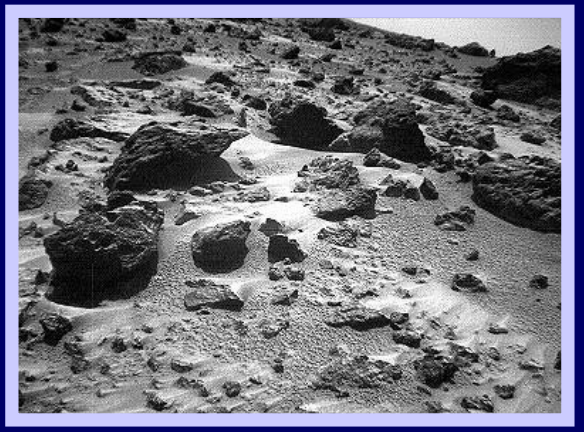
What about future missions?

MER

MSL

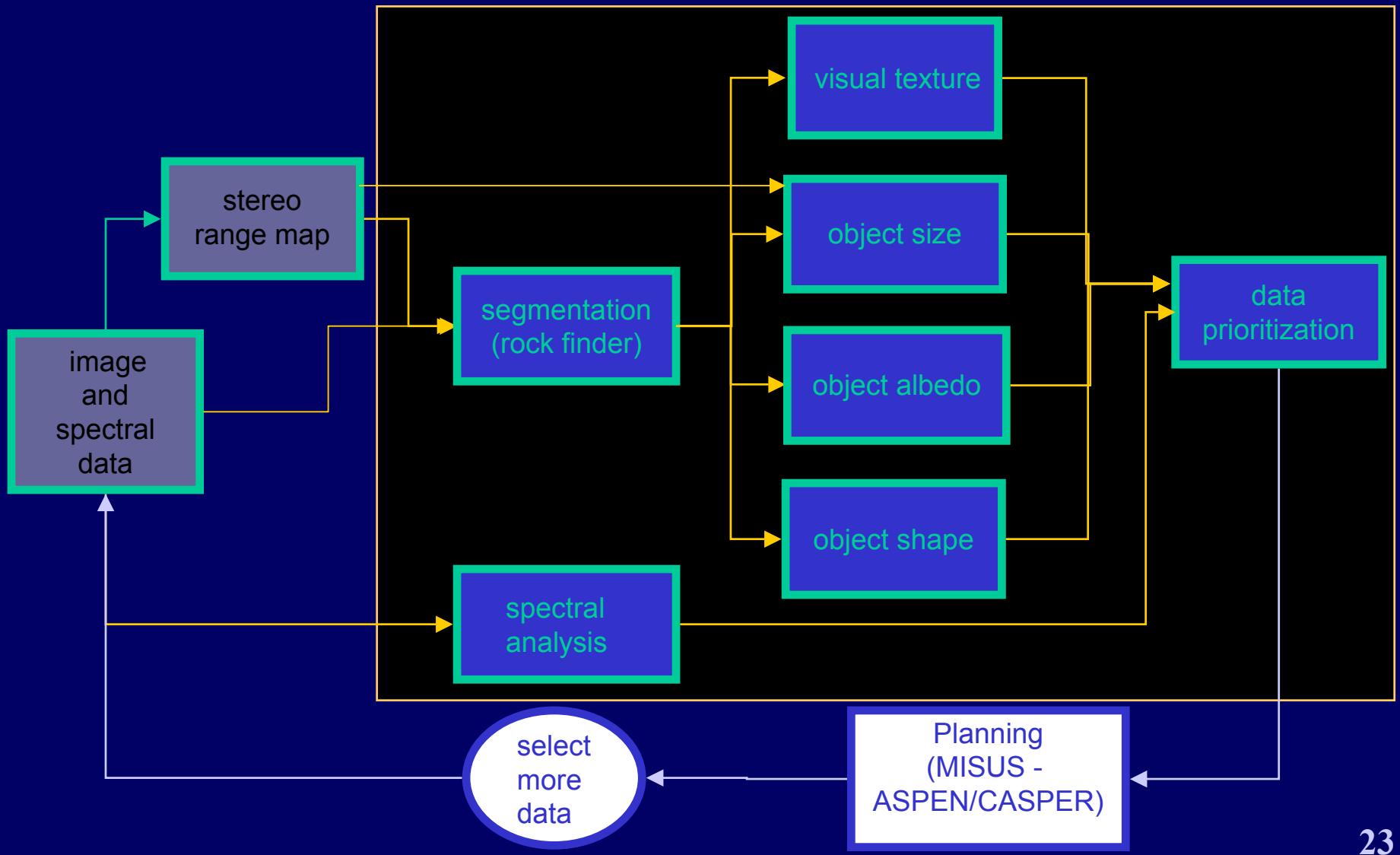
What Can Scientists Learn?

- Identify the “dinosaur bone”.
- Chemical compositions, e.g. carbonate detector.
- Separate soils from rocks
- Characterize the variety of rocks/soils
  - texture
  - albedo
  - shape and size
  - color
- Identify the rock distribution
- Characterize local and regional geology
  - how the landscape developed (e.g. fluvial, impact bombardment, aeolian, etc.)
  - the geologic history of the region



Rover Science Analysis Flow Diagram

Onboard Autonomous Science Investigation System



Agenda

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- **Technology under development**
  - Data analysis
  - Data prioritization and summary
  - Planning and scheduling
  - Software validation
- Conclusions

Technology to Achieve this Vision

Onboard Autonomous Science Investigation System

Data Analysis

- Rock/object identification
- Analysis of individually identified rocks

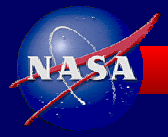
Data Prioritization and Summary

- Prioritization of data for downlink
- Clustering of rock feature information

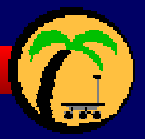
Planning and Scheduling

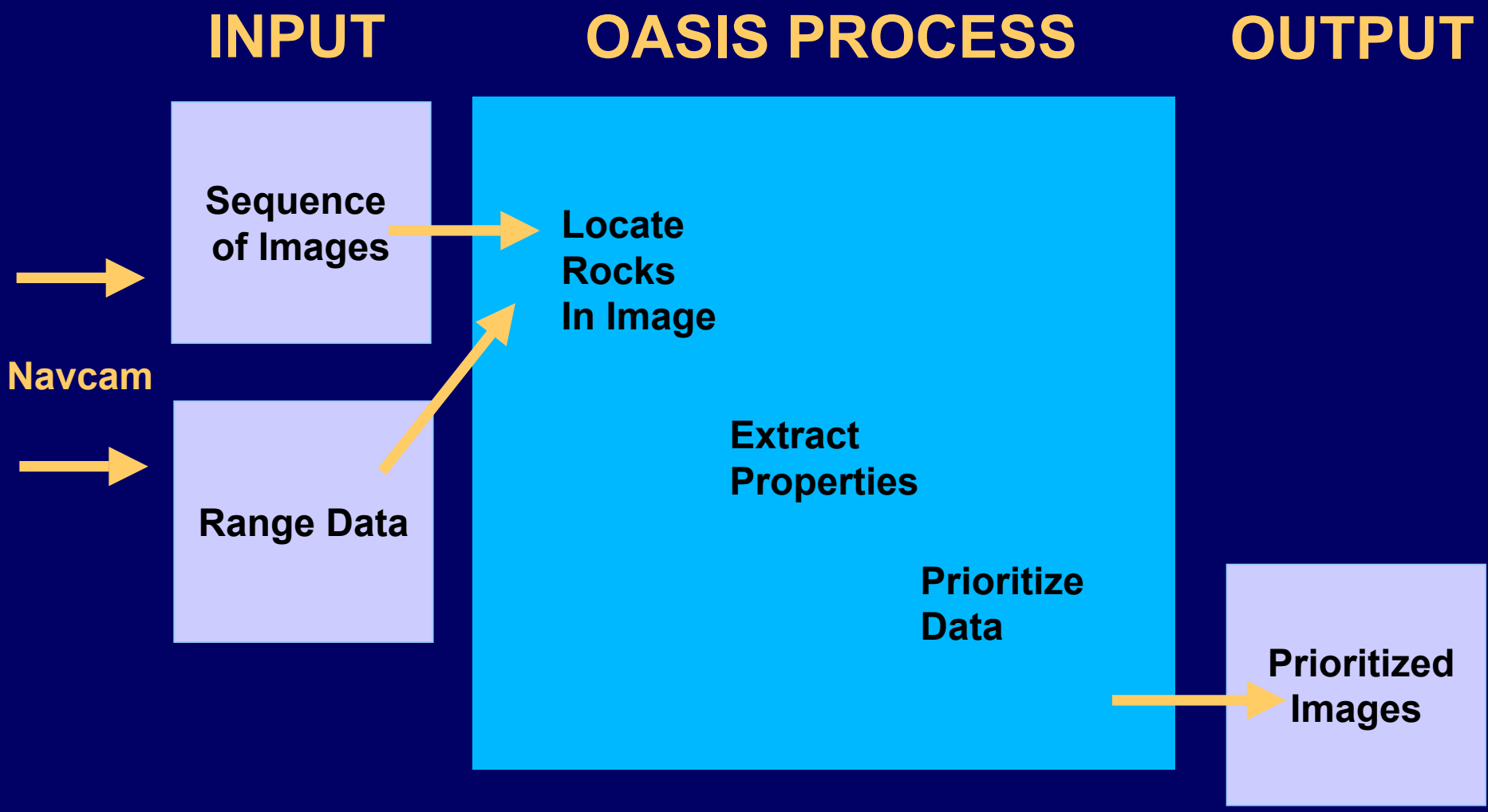
- Command sequence modification
- Resource and state analysis

OASIS Science Process



Onboard Autonomous Science Investigation System

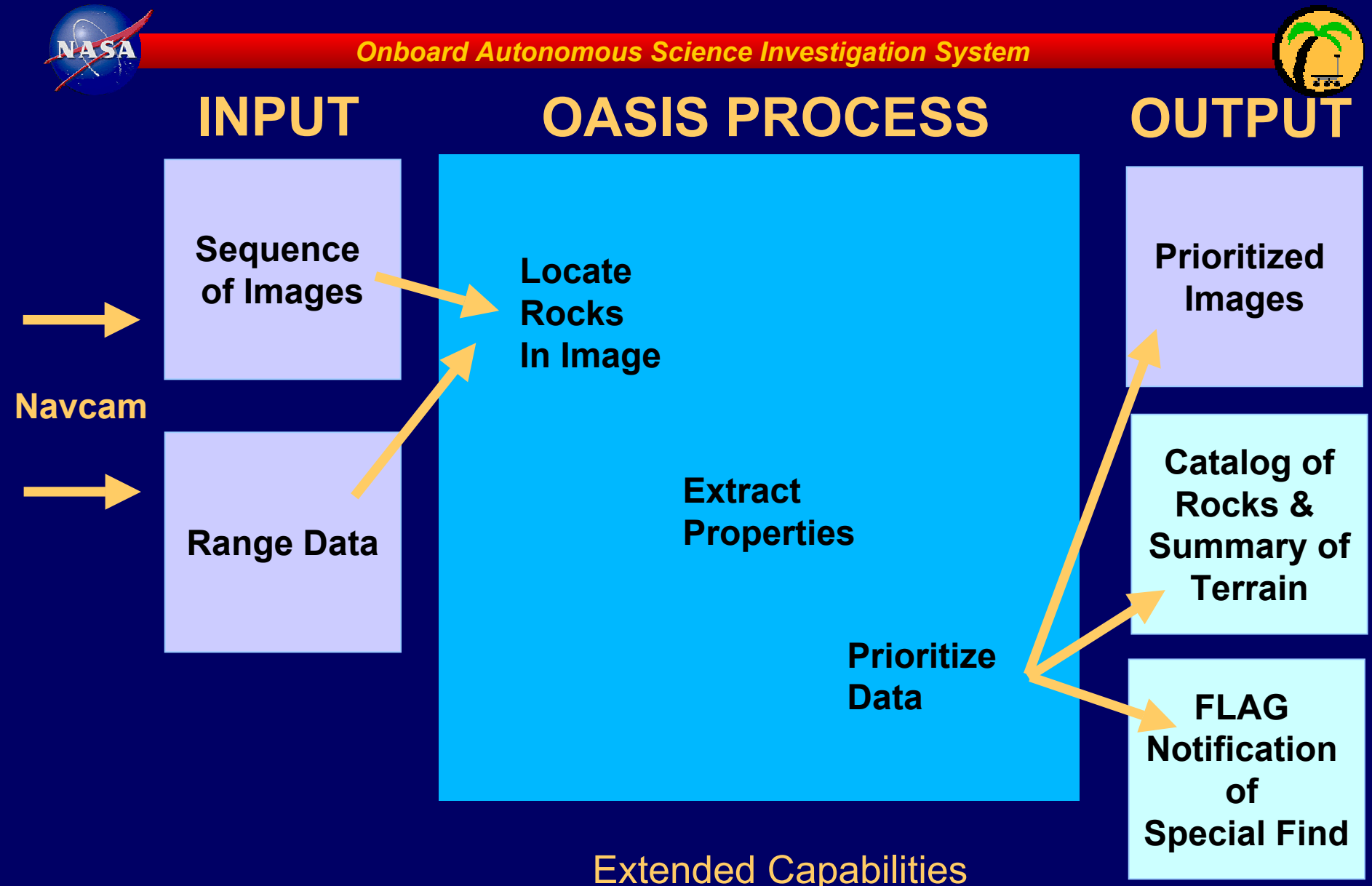




Base Level

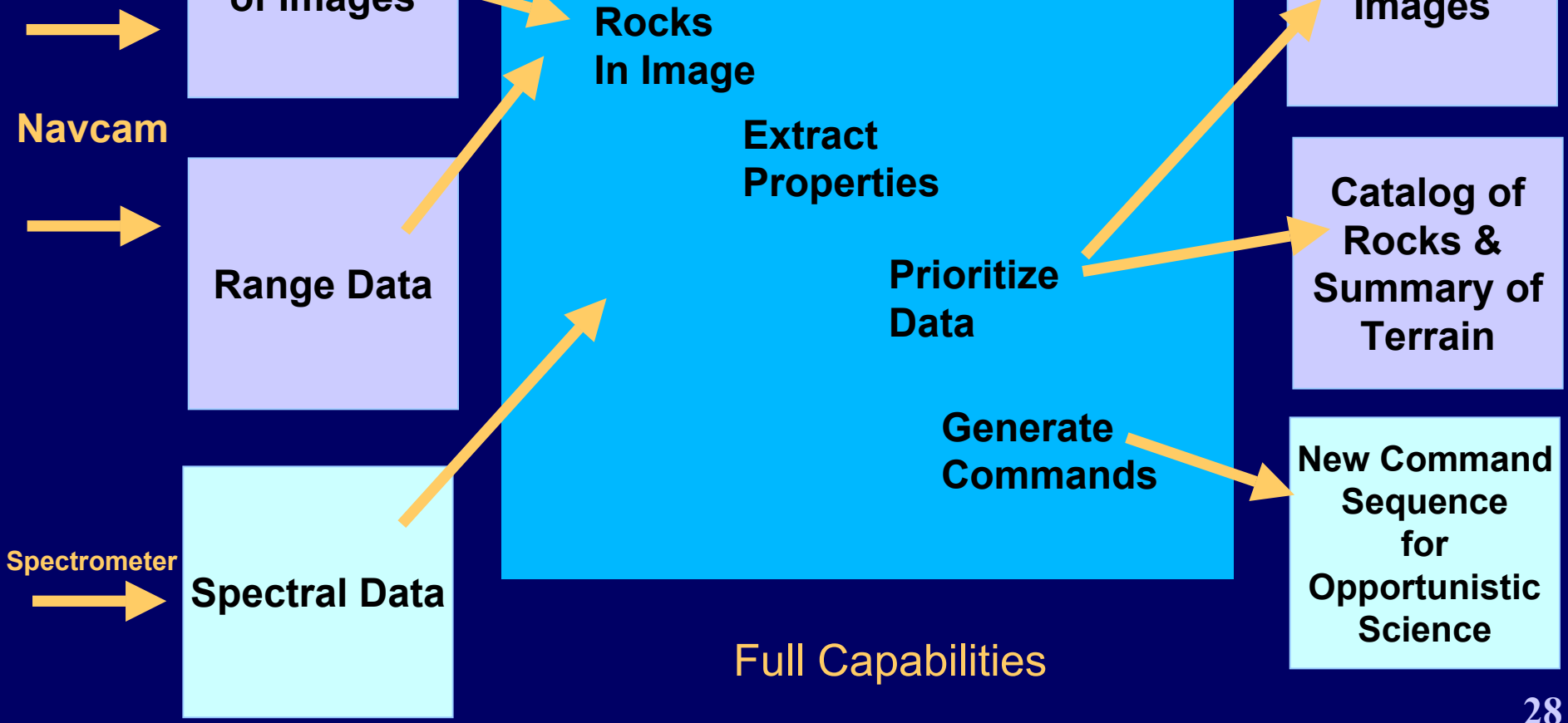
OASIS Science Process

Onboard Autonomous Science Investigation System



OASIS Science Process

Onboard Autonomous Science Investigation System



Data Analysis

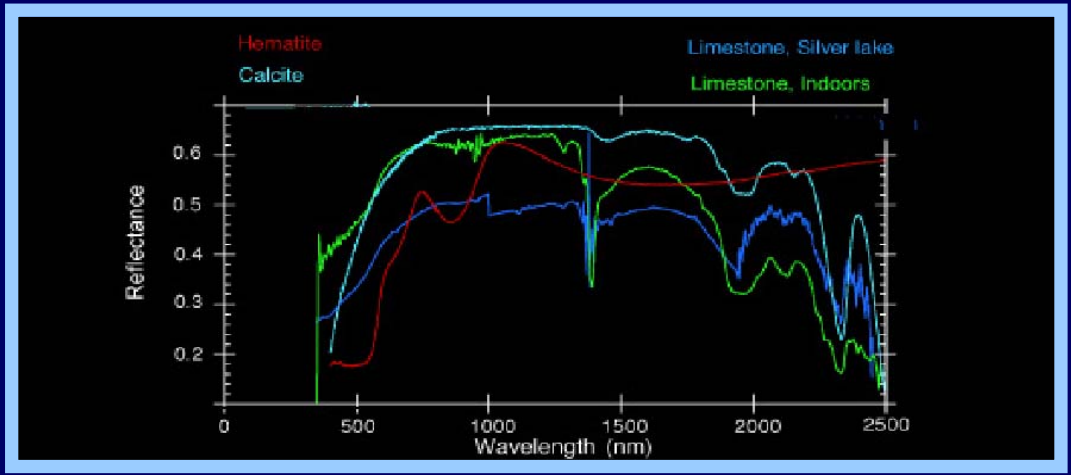
Onboard Autonomous Science Investigation System

Science Data Analysis

Spectral Analysis

Image Analysis

Spectral Analysis



Point spectra

- Hyperspectral
- Identify presence of minerals in select classes

Spectral images

- Multispectral (e.g. color image)
- Hyperspectral

Image Analysis

Rock/Object Detection

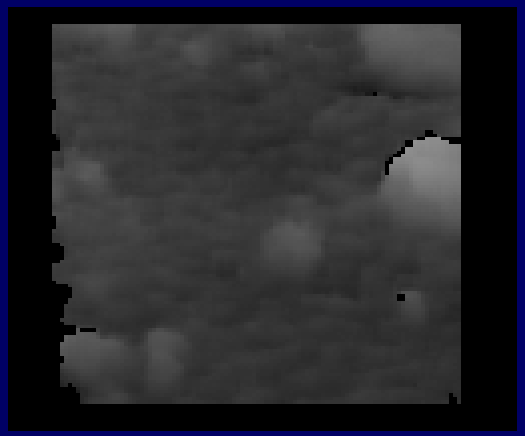
Individual Rock Property Analysis

- Texture
- Albedo
- Shape
- Size

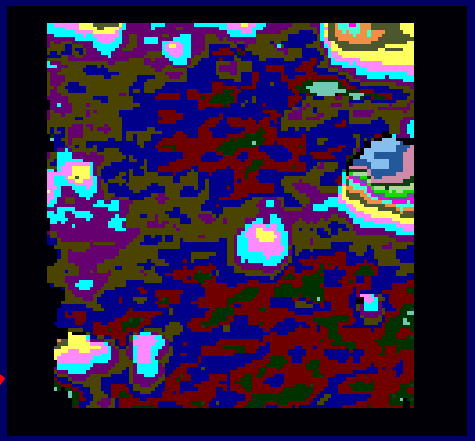
Rock Detection from Range Data

Onboard Autonomous Science Investigation System

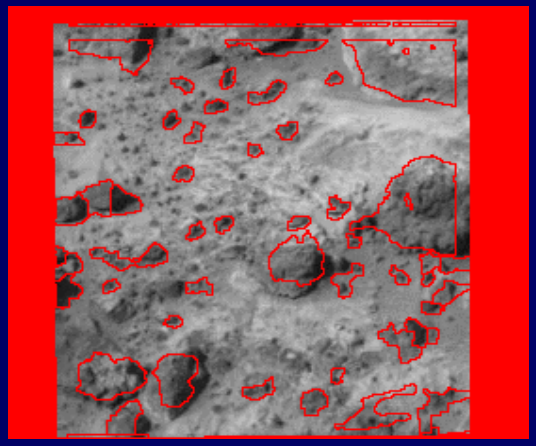
Original range image



Height image



Range-based elementary components



Final rocks

Victoria Gor

Individual Rock Property Analysis: Texture

Texture classes for surface vesicularity

Smooth

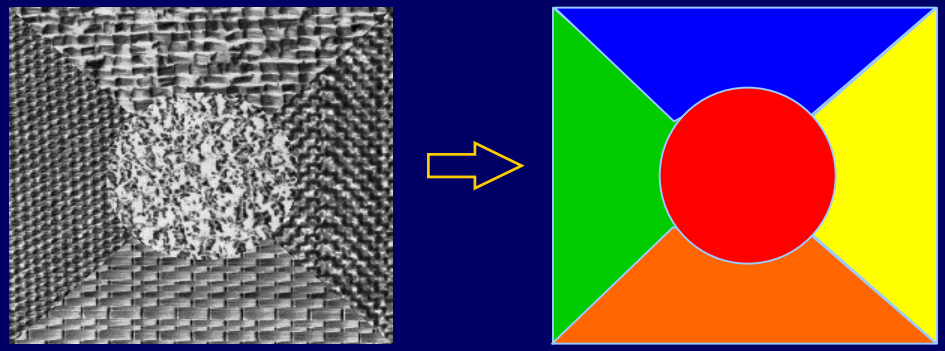
Highly vesicular

Visual texture provides information about geologic texture

Individual Rock Property Analysis: Texture Segmentation Results

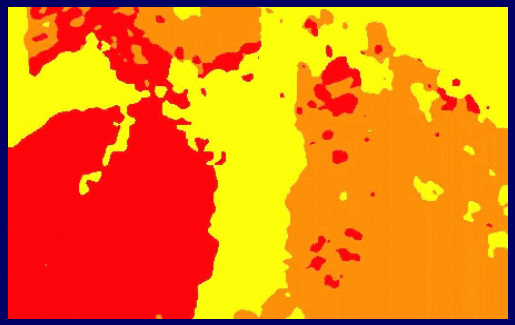
Onboard Autonomous Science Investigation System

Goal of texture segmentation:



Separate image into homogeneous regions

Igneous rock



Metamorphic rock

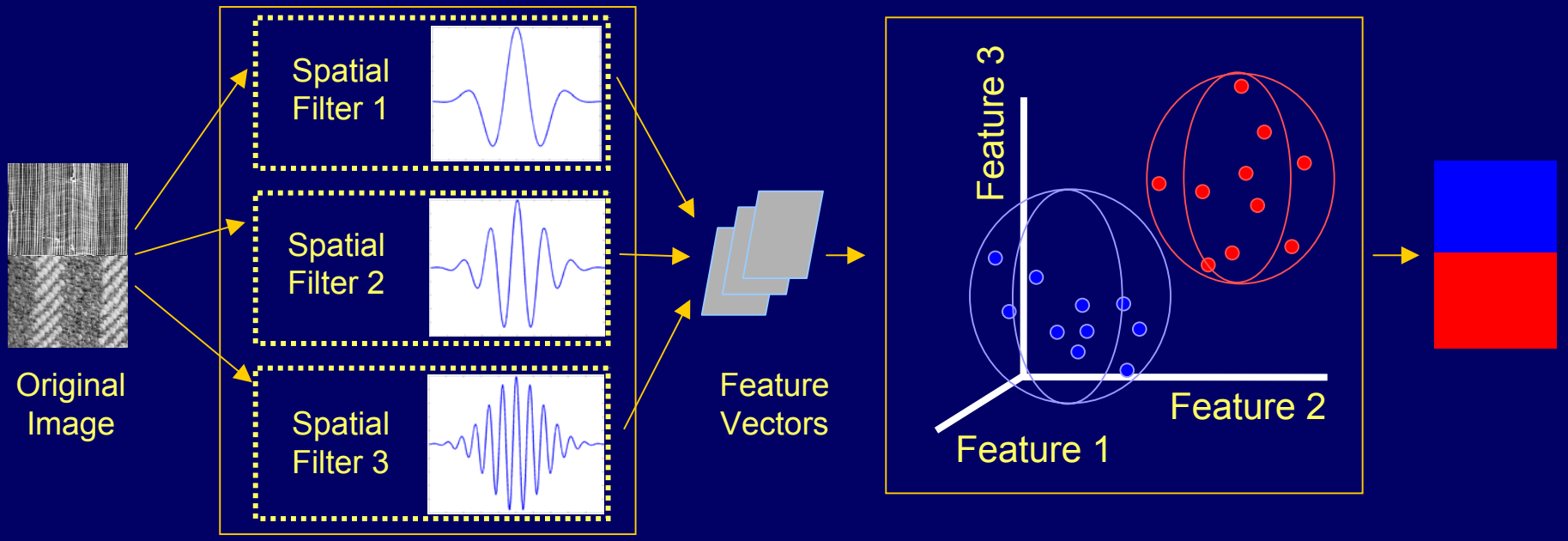
Sedimentary rock

Individual Rock Property Analysis: Texture Analysis Technique

Onboard Autonomous Science Investigation System

Extract features

Cluster



Filters are orientation and spatial frequency dependent

Individual Rock Property Analysis: Albedo

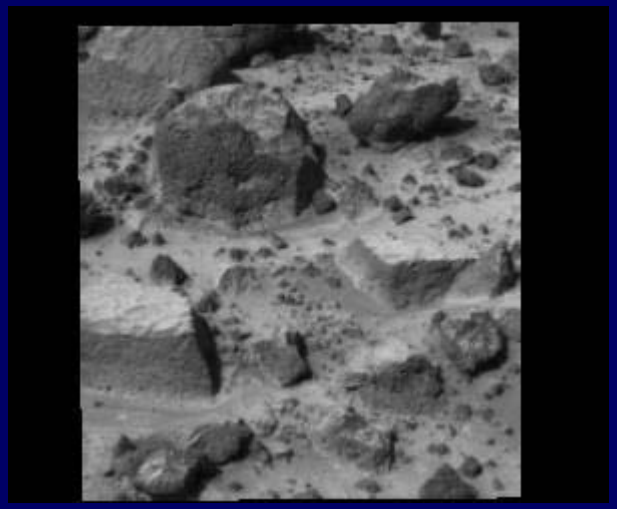
Onboard Autonomous Science Investigation System

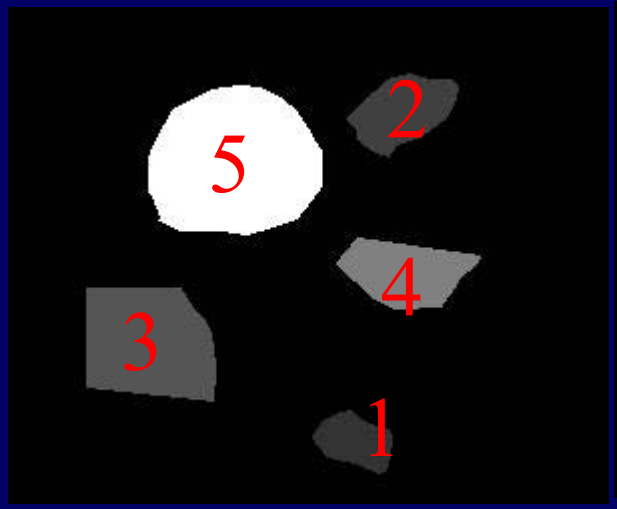
Light

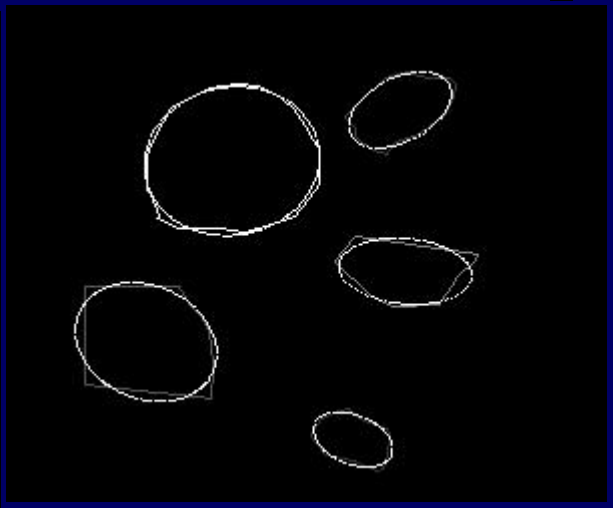
Dark

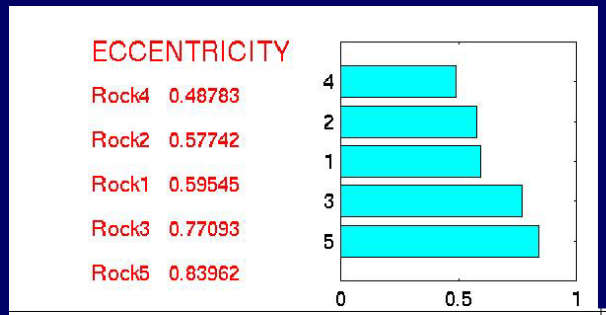
Individual Rock Property Analysis: 2D Shape Analysis

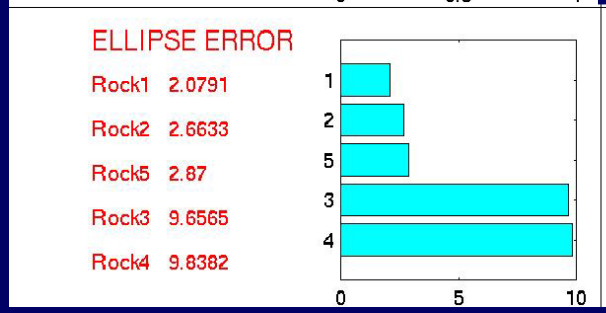
Onboard Autonomous Science Investigation System

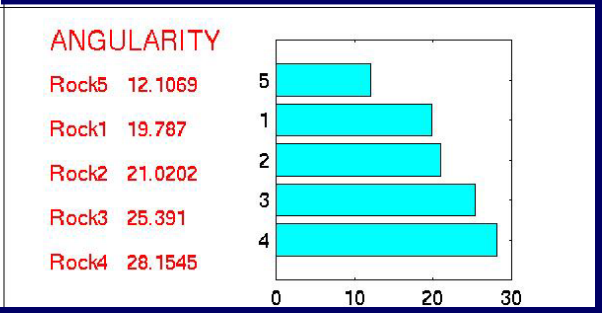






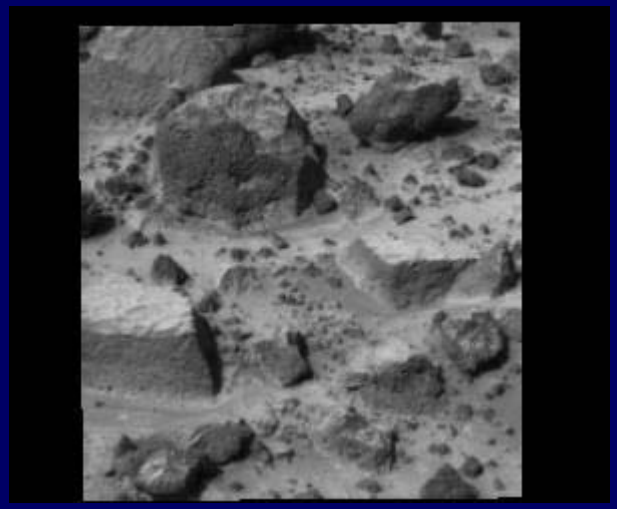


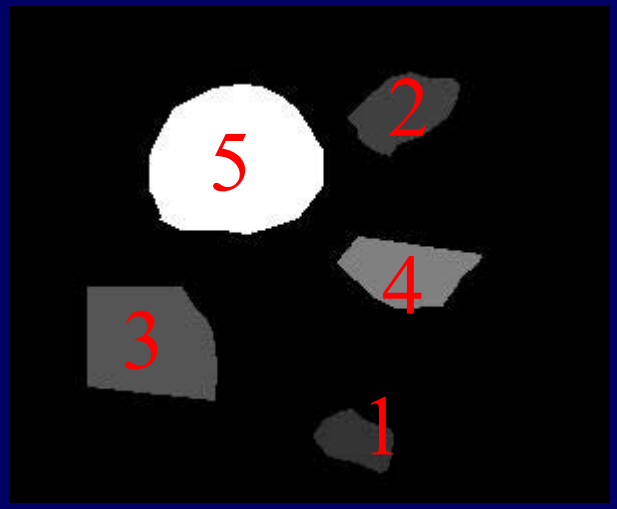


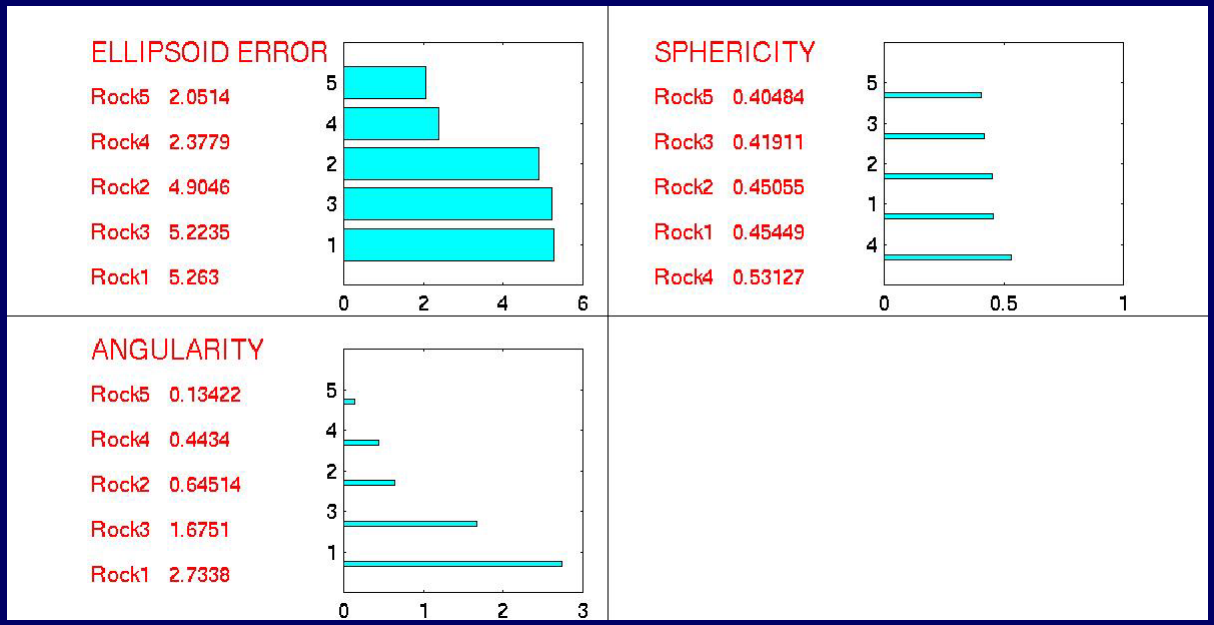


Individual Rock Property Analysis: 3D Shape Analysis

Onboard Autonomous Science Investigation System







Individual Rock Property Analysis
Shape: Angularity

Onboard Autonomous Science Investigation System

Angularity classes

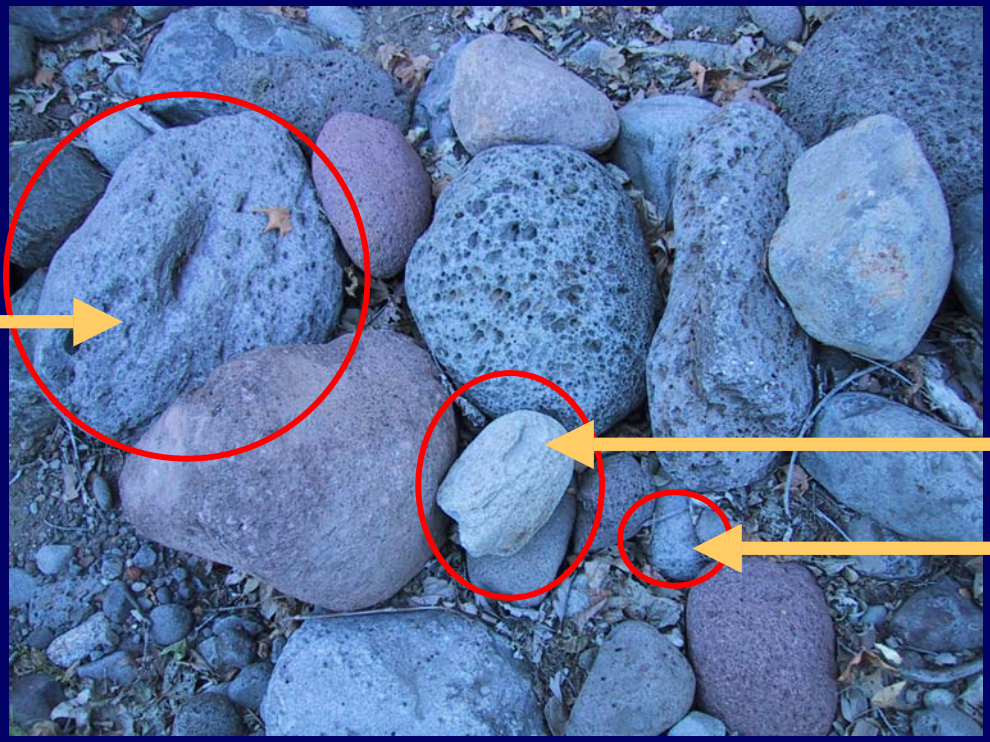
Rounded

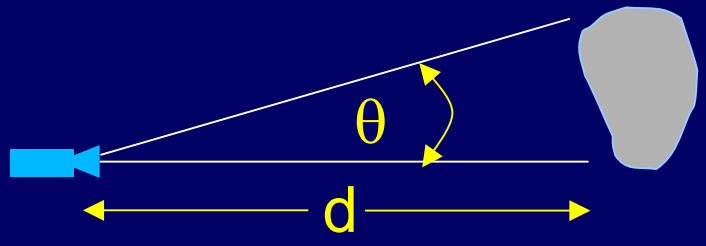
Sub-rounded/
Sub-angular

Angular

Individual Rock Property Analysis: Size

Onboard Autonomous Science Investigation System





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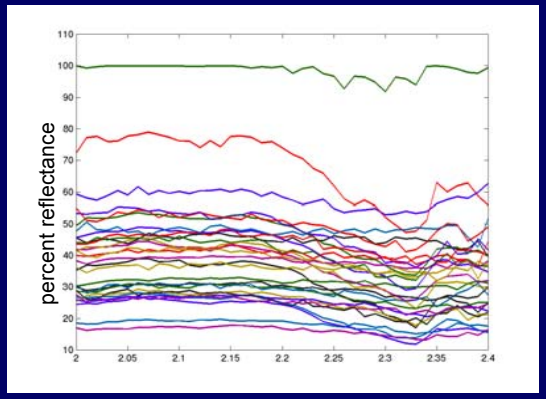
Prioritization – Key signatures

Carbonate Detector

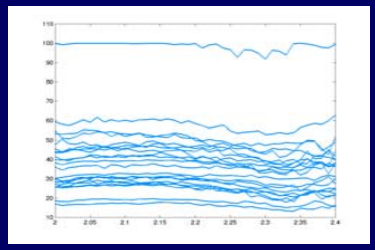
Trained neural network is used to separate rocks containing carbonate minerals from rocks that do not contain carbonate minerals

field collection site
Silver Lake, CA

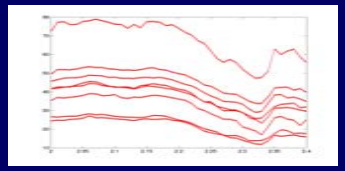


spectrometer
measurements

supervised
classification
(neural net)



noncarbonate



carbonate

Prioritization - Novelty

Clustering outliers
- Cluster all data

Mixture model outlier
- Train on all but test rock

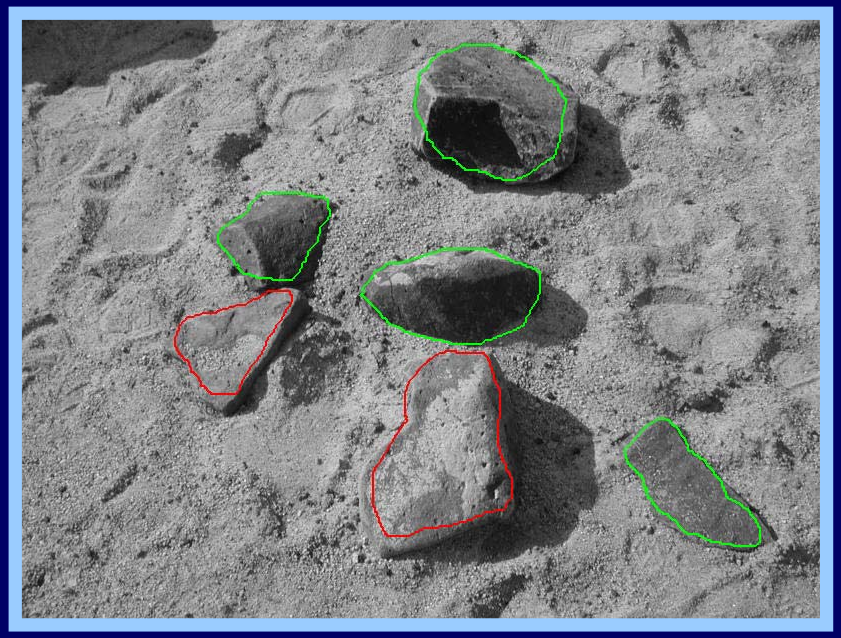
One-class discrimination
- Train on all but test rock

Dennis Decoste
And
Dominic Mazzoni

Prioritization – Cataloging

Unsupervised clustering ensures sampling each class of rock

Example data



clustering using albedo and texture

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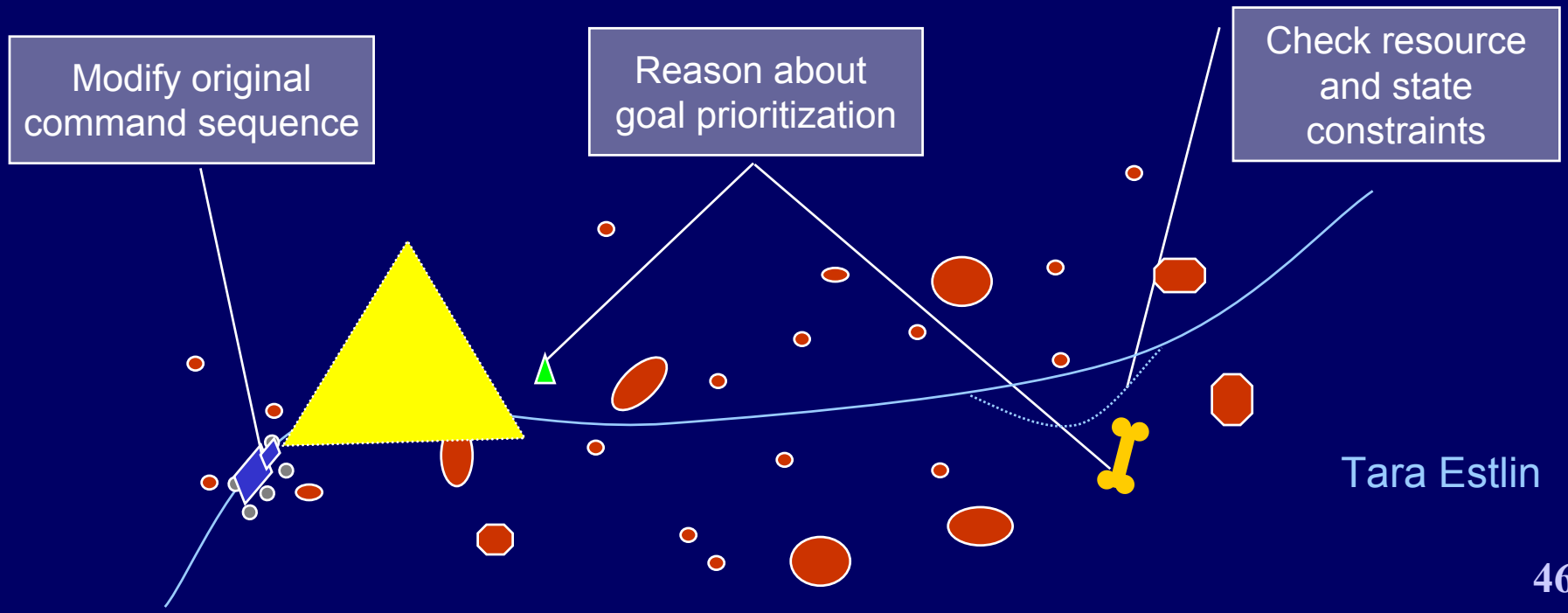
Planning Enabling to Traverse Science

- Applicable for 3 of 4 onboard science options
- Provides capability for adjusting the current command sequence to accommodate new science activities



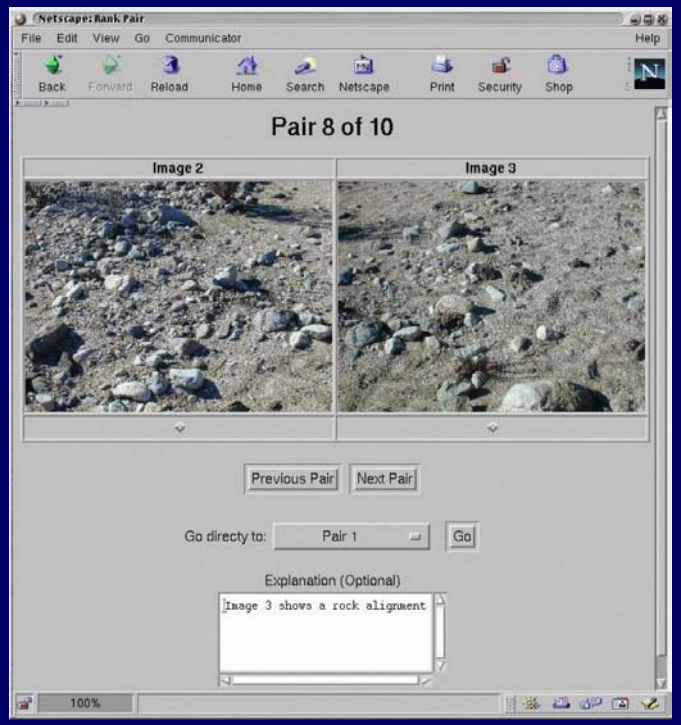
Validation

Compare automated prioritization to expert prioritization of same data

Prioritization compared to ground truth as verified by experts at the field site

Testing data

- Pathfinder
- Mars yard – Rocky 8, FIDO, digital camera
- Field data – FIDO, digital camera, IPS
- Portable stereo platform



GUI for collecting expert ranking of data set

Agenda

- Overview of traverse science scenarios
- Scientific motivation
- Technology under development
  - Data analysis
    - Spectral analysis
    - Rock detection
    - Rock property extraction
  - Data summary
    - Clustering
    - Prioritization
  - Planning and scheduling
  - Validation
- **Conclusions and Summary**

Future Work

- Combine three prioritization methods
- Include spatial information on rock locations
- Expand spectral analysis to new rock classes (sulfates, etc.)
- Expand from point spectral analysis to spectral images
- Data fusion from multiple instruments

Summary

- Traverse science will
  - Help to resolve the conflict between long driving requirements and science
    - Geologists are afraid they are going to miss opportunities for science.
    - Increase mobility and resource utilization.
  - Increase total mission science return.
  - Not replace geologists on the mission!!!
- Technology advances to enable traverse science are under development

OASIS Contributors

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- Mars Tech

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Questions?